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DEVELOP AND FABRICATE A RADIATION DOSE MEASUREMENT SYSTEM FOR SATELLITES

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A second generation Dosimeter is being designed to fulfill the need for accurate radiation dose measurements. Two identical Dosimeters, a flight unit and a backup unit, are to be fabricated, tested and calibrated. The flight Dosimeter is to be integrated into the payload of the Advanced Photovoltaic Electronic Experiment (APEX) satellite, as part of the Photovoltaic Array Space Power Plus Diagnostics (PASP Plus) experiment.

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1. INTRODUCTION

Accurate characterization of the space radiation environment is one of the important inputs into the design of space systems which utilize complex electronic components. Radiation dose information can be used to optimize the design of a space system in terms of its expected lifetime, the types of electronic parts that can be used and the shielding required for its critical components.

Electronic devices, photovoltaic power systems, and spacecraft surfaces are susceptible to damage due to the received radiation dose from incident energetic protons and electrons. In addition, many types of electronic parts, particularly microprocessors and associated memory units, are subject to single event upsets (SEU's) caused by the passage of single high energy heavy ions through the device or high energy proton induced "nuclear star" events. The instantaneous radiation dose rate, and the associated total accumulated dose, provide important information for the estimation of satellite lifetime and for real-time decisions regarding satellite integrity. This information can be used to provide advance warning of when critical components are approaching failure due to radiation damage, and it can also provide confidence in the reliable operation of a component by showing that the radiation damage is not yet significant. In the case of solar flares, a dose measurement could show that radiation exposure has, perhaps suddenly, become very important and that the consequences must be dealt with as appropriate.

The increasing use of complex solid state electronic devices in the space radiation environment makes it important to have reliable data on the radiation doses these devices will receive behind various thicknesses of shielding. As part of the effort to obtain this data a Dosimeter was designed, fabricated, calibrated, and integrated into the payload of a Defense Meteorological Satellite Program (DMSP) satellite by Panametrics, Inc., for the Geophysics Laboratory, under contract number F19628-78-C-0247. A second, essentially identical, Dosimeter was designed, fabricated, calibrated, and integrated into the payload of the Combined Release and Radiation Effects Satellite (CRRES) by Panametrics, Inc., for the Geophysics Laboratory, under contract number F19628-82-C-0090. The DMSP and CRRES Dosimeters, which measure the accumulated radiation dose in four silicon solid state detectors behind four different thicknesses of aluminum shielding (one solid state detector behind each shield), are described in Refs. 1 and 2, respectively.

The general objective of the current contract is the design and fabrication of an improveu, second generation, Dosimeter intended to fulfill the need for accurate radiation dose measurements. This system is to have the following characteristics:

1) Separately measure the total accumulated dose due to electrons and protons,
2) Detect and measure energy deposition of large energy deposition events (possible SEU's),
3) Accurately measure the dose during normal activity periods and during large solar flare events (such as August 1972 or March 1989),
4) Be easily adaptable mechanically and electronically to different spacecraft and different radiation environments (for example orbits inside or outside the radiation belts),
5) Have modest telemetry requirements.

The specific objectives of this contract are as follows:

1) Conceptual design of a Dosimeter instrument which meets the five requirements listed above,
2) Detailed design of the Dosimeter instrument,
3) Fabrication, testing and delivery of the protoflight[1] Dosimeter unit,
4) Fabrication, testing and delivery of the backup[1] flight Dosimeter unit.

The protoflight[1] Dosimeter is to be integrated into the payload of the Advanced Photovoltaic Electronic Experiment (APEX) satellite, as part of the Photovoltaic Array Space Power Plus Diagnostics (PASP Plus) experiment.

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1. The "protoflight" and "backup" designations are specified in the contract. The "protoflight" Dosimeter and "backup" Dosimeter are both fully qualified flight instruments.

2. PROGRESS TO DATE

2.1 Detection System

An isometric drawing of the Dosimeter is shown in Figure 1. The preliminary interface control drawing is shown in Figure 2, and the instrument's preliminary block diagram is shown in Figure 3.

The integral particle flux and radiation dose is measured by solid state detectors located behind degraders and backed by a large amount of shielding, which reduces the response to rear entry particles. As shown in Figures 1 and 3, the instrument has four degraders (3 hemispherical and 1 planar, all of which are referred to as "domes") with solid state detectors located underneath them. Dome 1 was specially configured as a planar Al shield 4.3 mils thick to allow accurate dosimetry measurements of the particles (5-10 Mev protons) most likely to cause solar cell degradation. This was necessary to meet PASP Plus requirements. The two thinnest domes have two detectors under each dome, one with a large sensitive volume and one with a small volume. The purpose of this arrangement is to ensure a large dynamic range of the instrument, the small detector will work reliably even with very high flux levels that may paralyze the larger detector. A summary of the detector characteristics is give in Table 1. A cross sectional view of D1, the planar and thinnest dome, is shown in Figure 4. A cross sectional view of D3, which is typical of the three hemispherical domes except that there are two solid state detectors under D2, is shown in Figure 5.

Protons and electrons which penetrate the degraders will deposit, on the average, different amounts of energy in the solid state detectors, and so their contributions to the total dose can be separated. The solid state detectors are approximately 400 μm thick and most penetrating electrons deposit less than 1 MeV of energy in them, while most penetrating protons deposit between 1 and 10 MeV. A summary of the dome moderators utilized, and the resultant threshold energies, is given in Table 2. Energy deposition curves for the four domes are shown in Figures 6-9. The electron flux measurements with the thicker domes may not be reliable due to the production of bremsstrahlung by low energy, non-penetrating electrons. The total electron radiation dose will, however, still be correctly determined. The flexibility of this design approach is that the same physical envelope of the dome-detector assembly can be used for very different degrader thicknesses and detector configurations. Thus, a simple mechanical change can be used to tailor the proton and electron thresholds to the specific mission requirements.

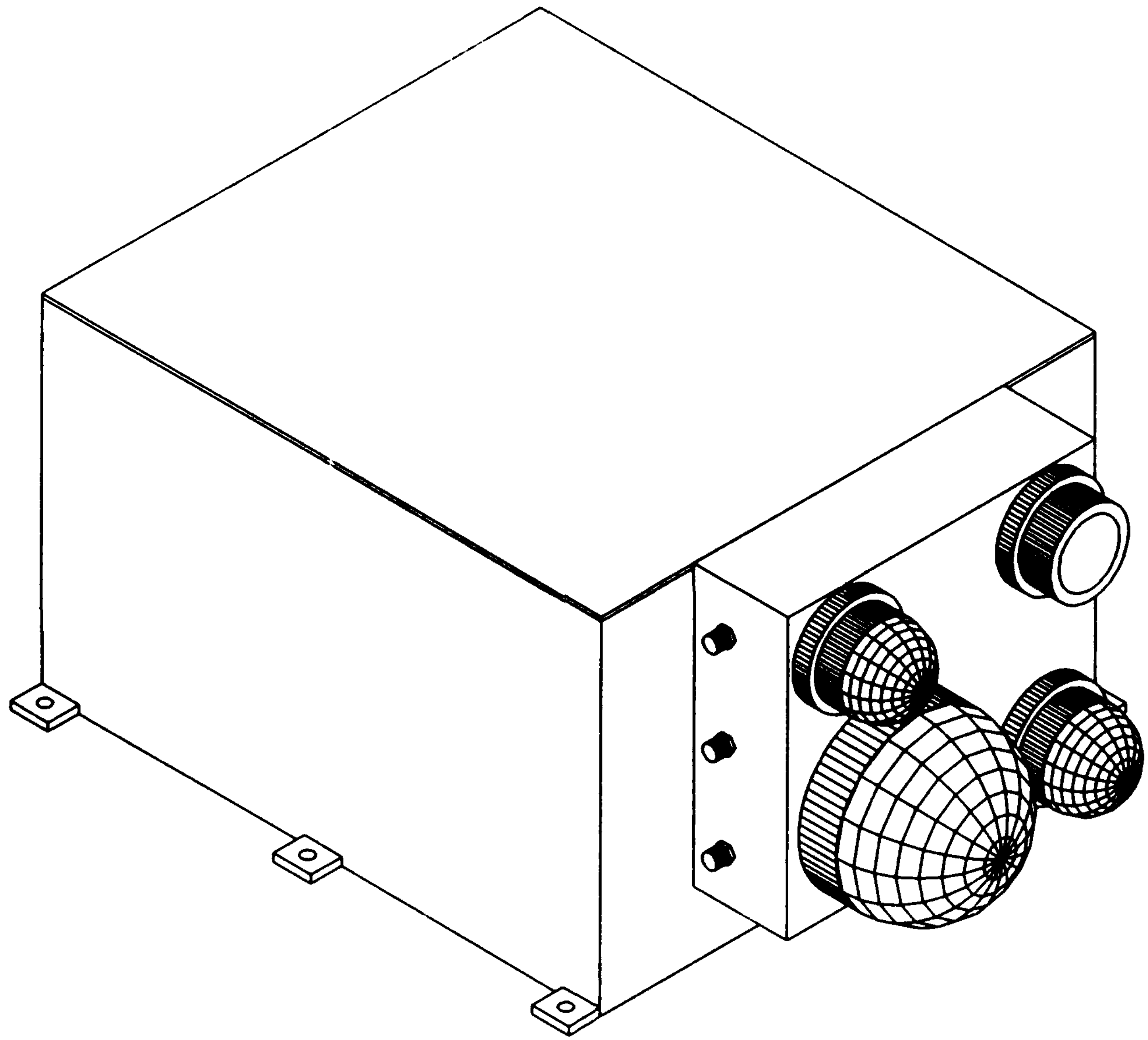

Figure 1. ISOMETRIC VIEW OF DOSIMETER

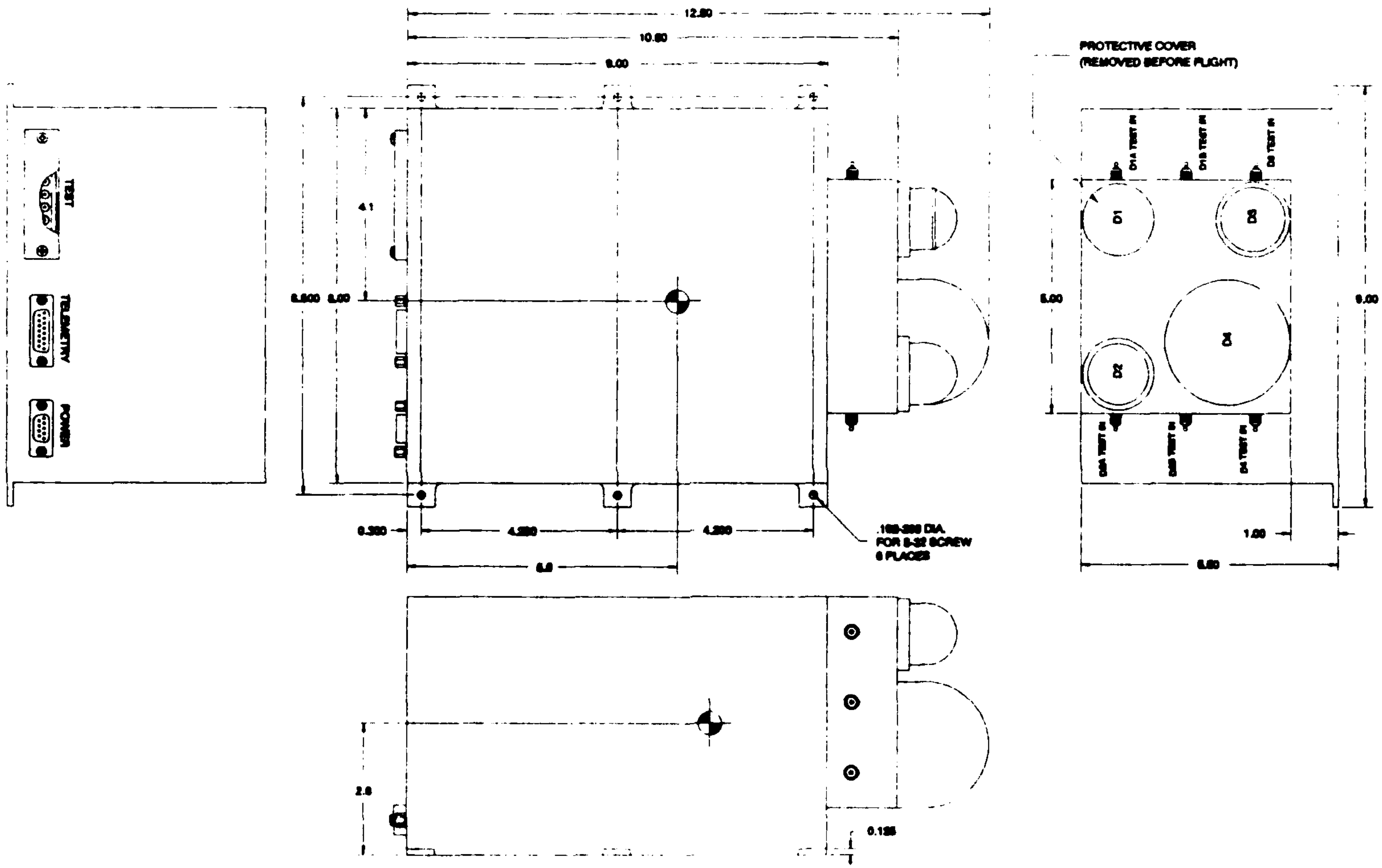

Figure 2. PRELIMINARY INTERFACE CONTROL DRAWING

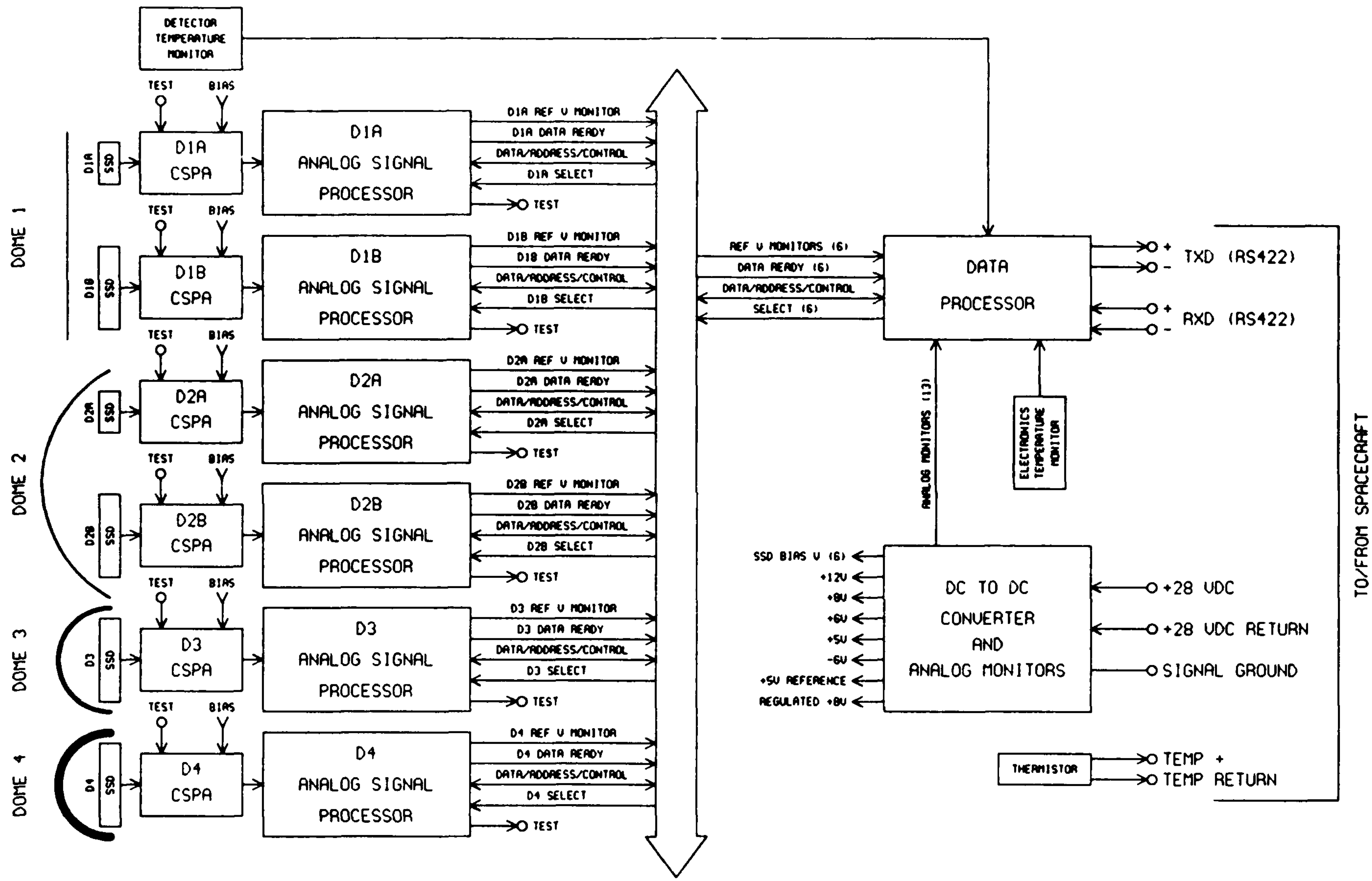

Figure 3. ELECTRONICS BLOCK DIAGRAM

Table 1.
SUMMARY OF DETECTOR CHARACTERISTICS

Telemetry Channel Number	Dome	Detector		Dose at Overflow (Rads Si)		Flux at Overflow (part/(cm^2-s))		
		Designation	Area (cm^2)	LOLET	HILET	TOTAL	LOLET	HILET
1	D1	D1A	0.008	10^6	10^7	10^9	10^8	10^8
2	D1	D1B	0.051	10^5	10^6	10^8	10^7	10^7
3	D2	D2A	0.008	10^6	10^7	10^9	10^8	10^8
4	D2	D2B	0.051	10^5	10^6	10^8	10^7	10^7
5	D3	D3	0.051	10^5	10^6	10^8	10^7	10^7
6	D4	D4	1.000	10^4	10^5	10^7	10^6	10^6

Table 2.
DOME MODERATORS AND ENERGY RANGES

Dome	Detectors	Aluminum Shields		Electron threshold	Proton energy range	VHILET threshold
		(g/cm^2)	Shape	(MeV) (LOLET)	(MeV) (HILET)	(MeV)
D1	D1A, D1B	0.0294	flat	0.15	5 - 80	40, 40
D2	D2A, D2B	0.55	hemisphere	1.0	20 - 115	40, 40
D3	D3	1.55	hemisphere	2.5	32 - 120	40
D4	D4	3.05	hemisphere	5.0	52 - 125	75

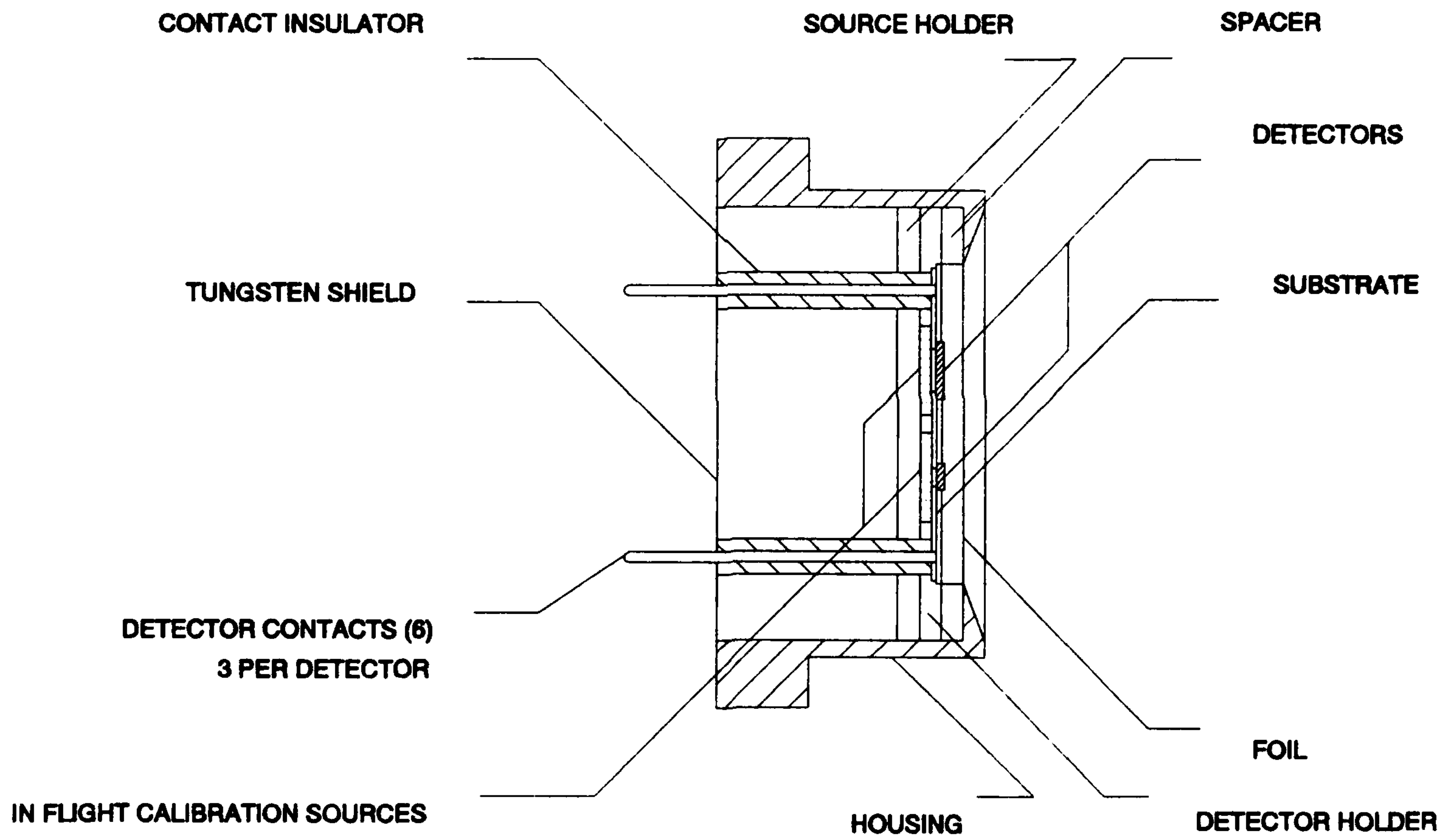

Figure 4. DOME 1 CROSS SECTION

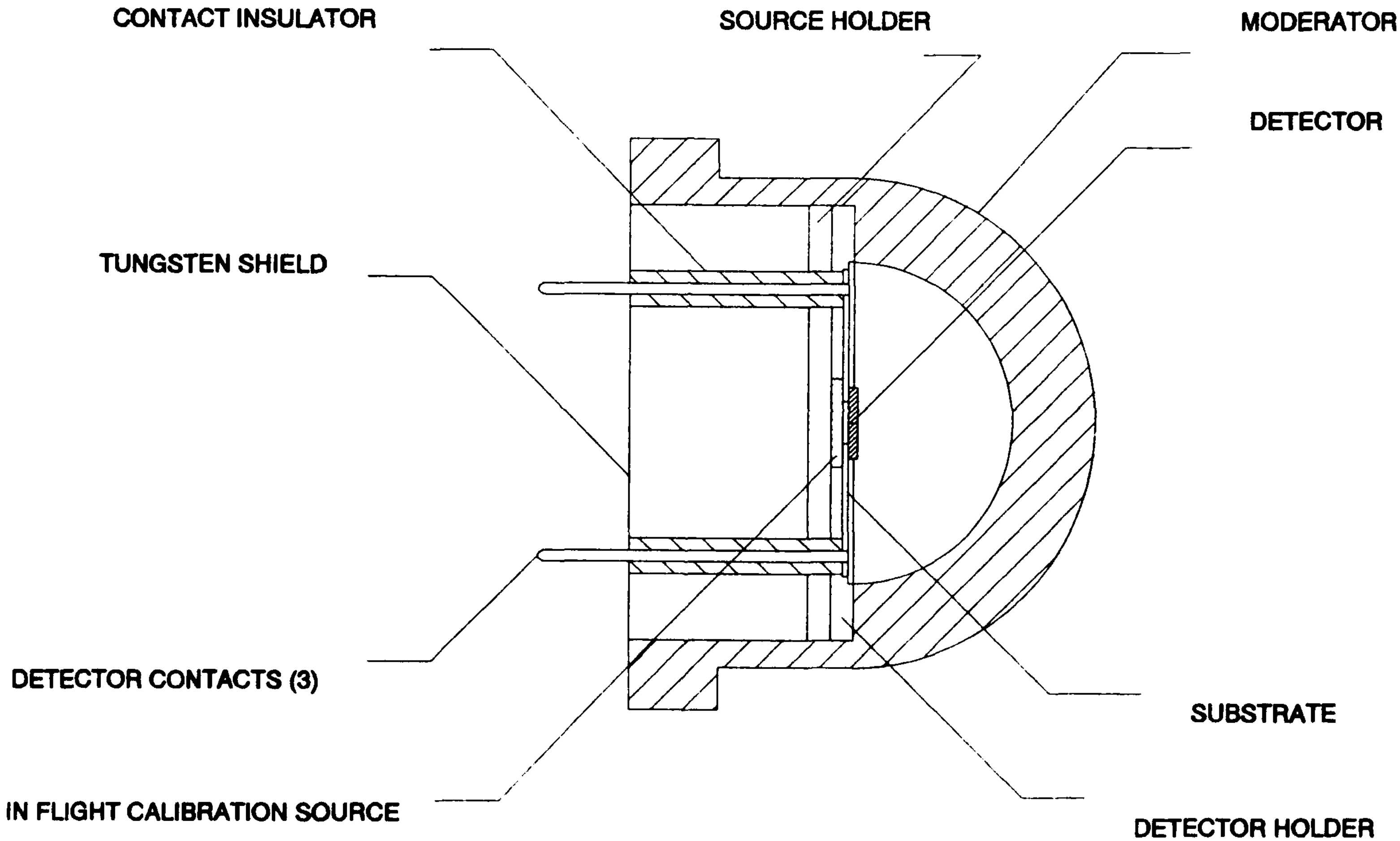

Figure 5. DOME 3 CROSS SECTION

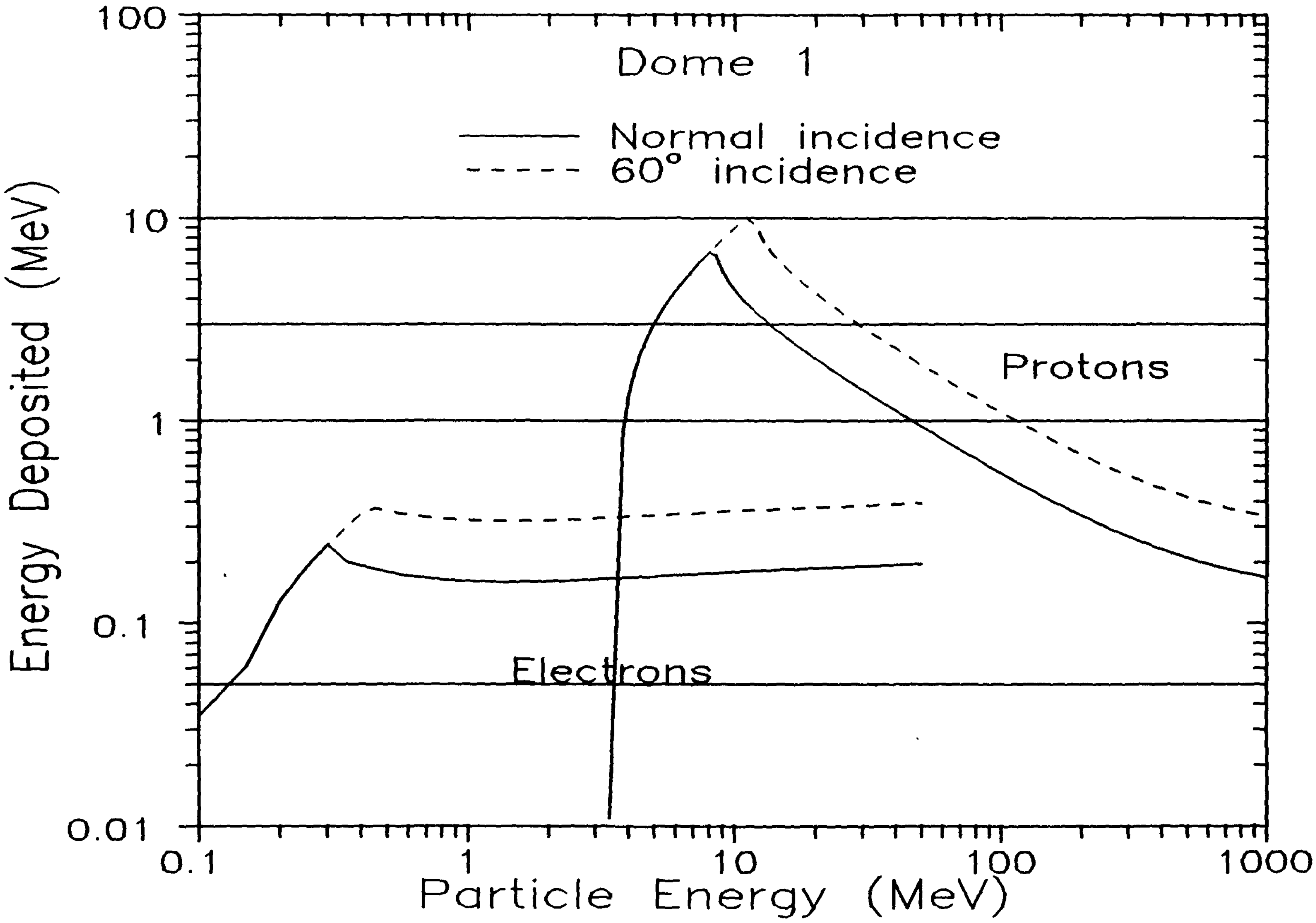

Figure 6. DOME 1 ENERGY DEPOSITION CURVES

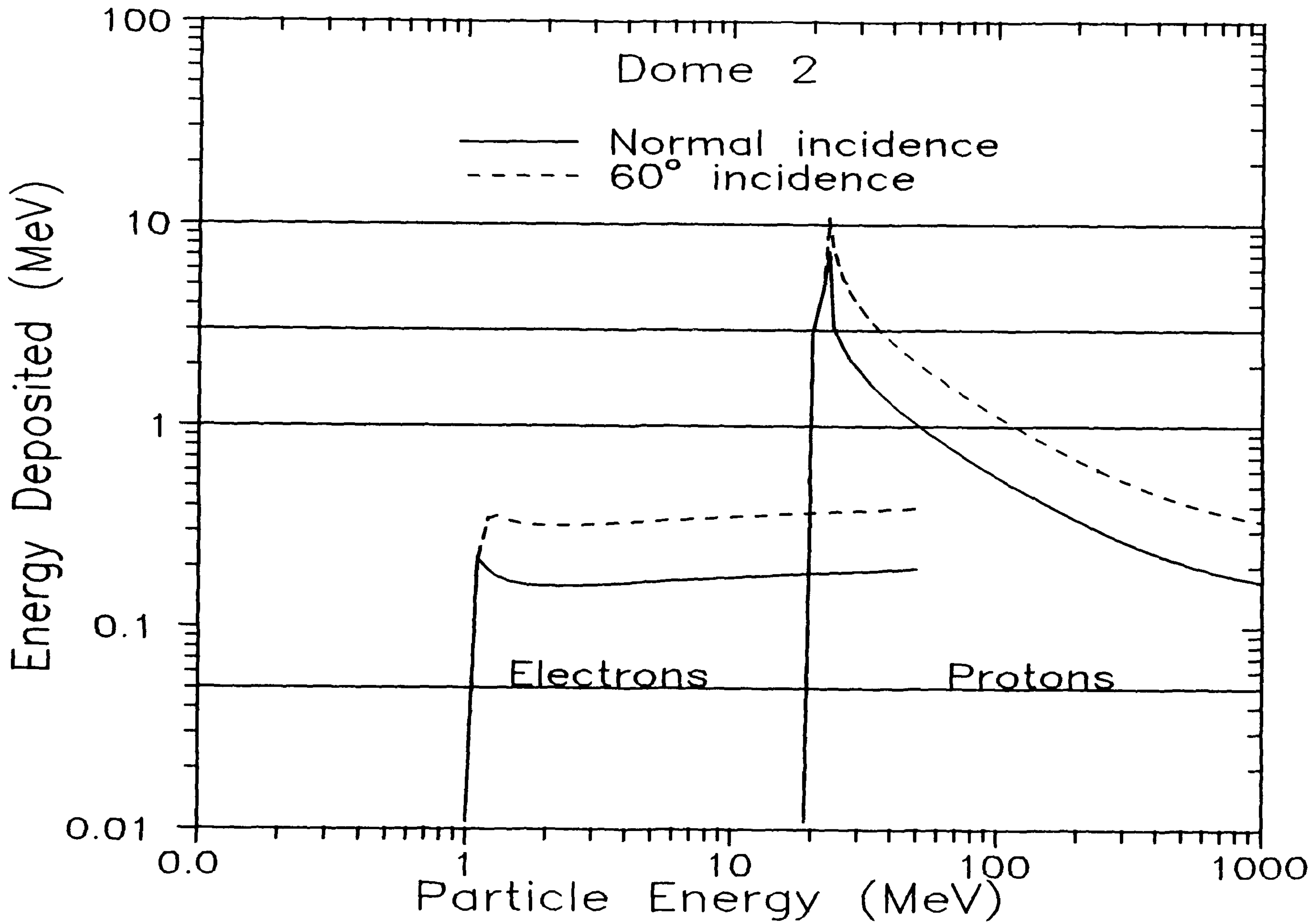

Figure 7. DOME 2 ENERGY DEPOSITION CURVES

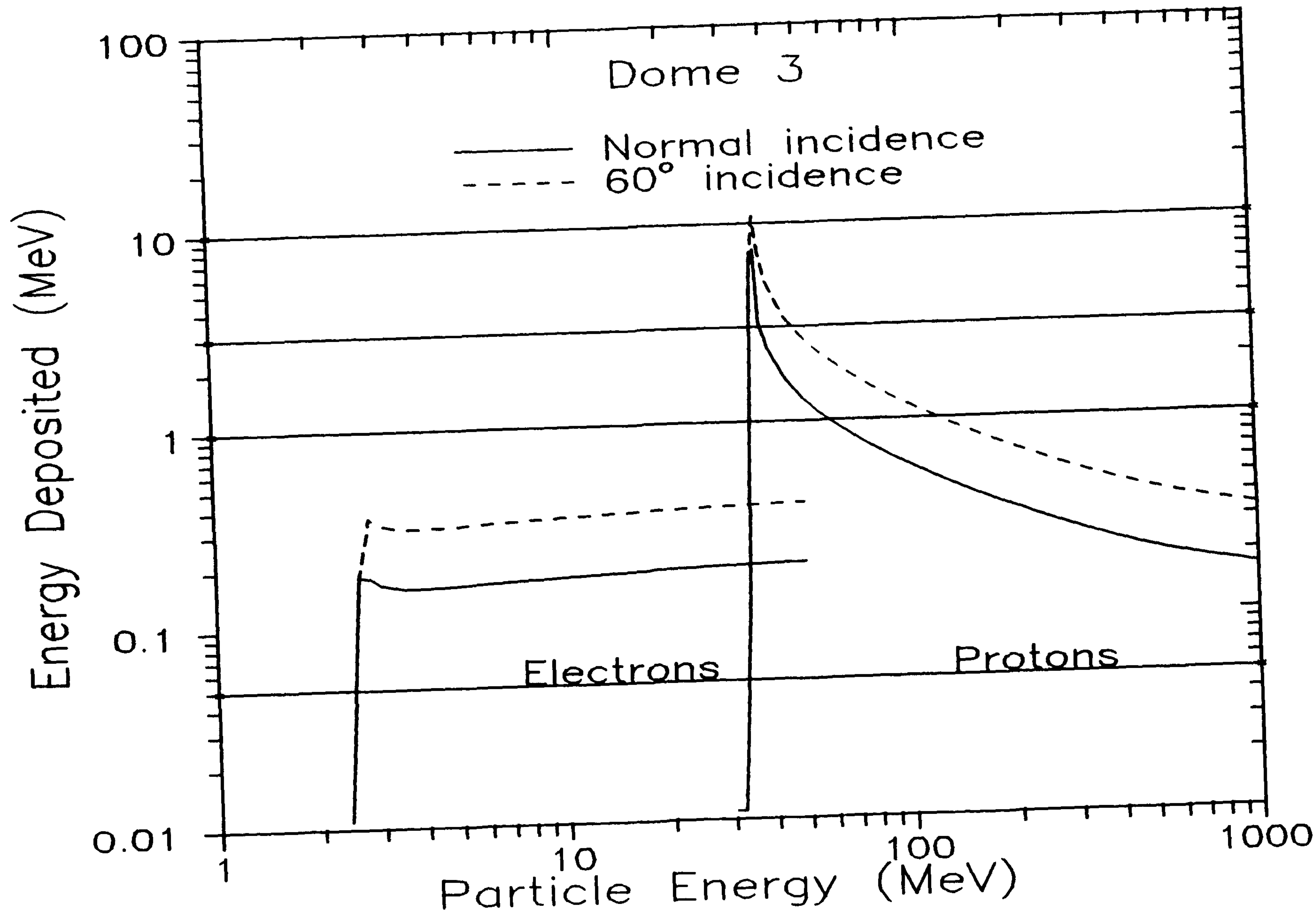

Figure 8. DOME 3 ENERGY DEPOSITION CURVES

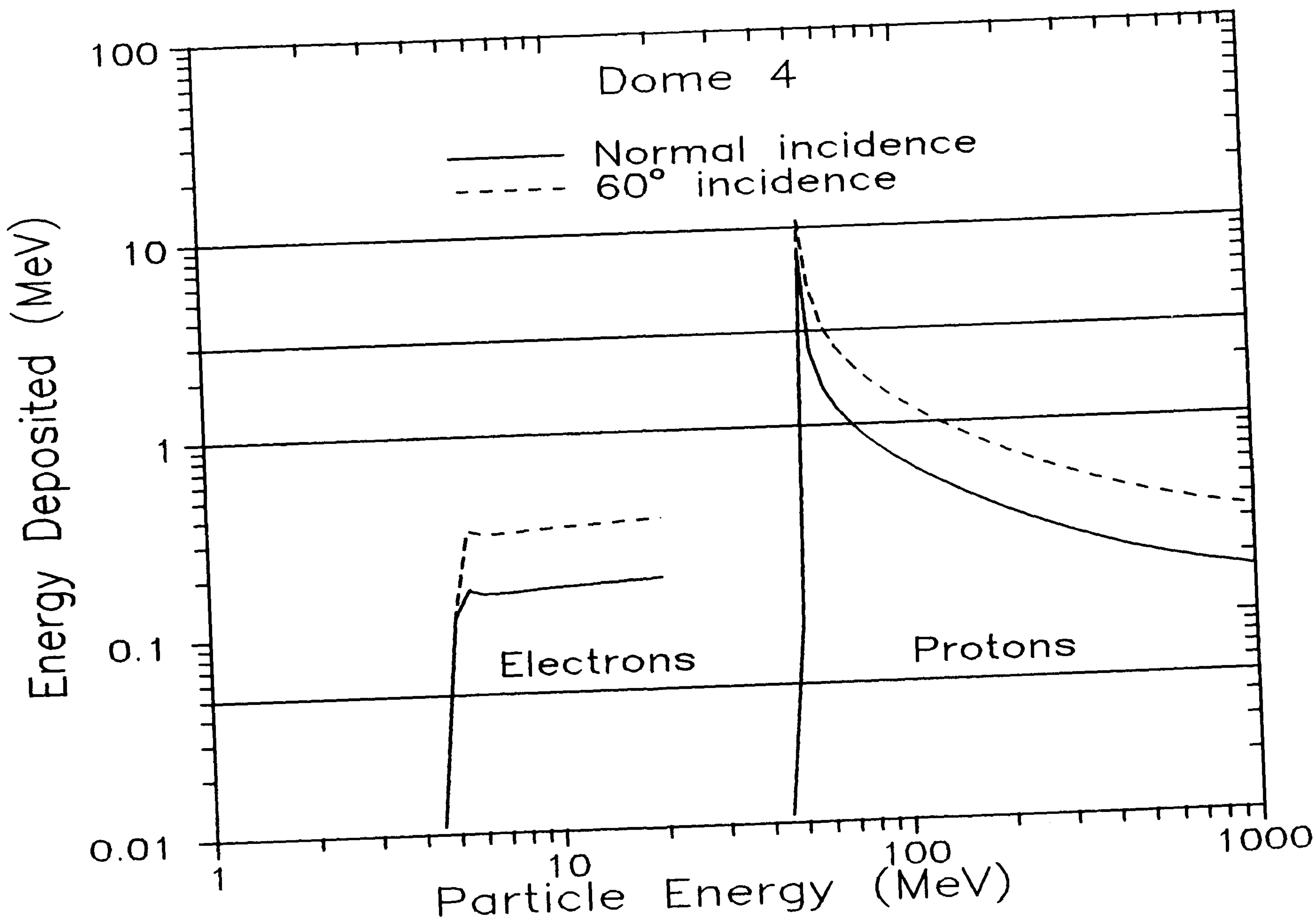

Figure 9. DOME 4 ENERGY DEPOSITION CURVES

2.2 Signal Processing

Signals from each solid state detector are amplified and digitized by the analog signal processors (ASP's). There are six (6) identical ASP's, one for each solid state detector. Each ASP includes hybrid amplifiers and a fast, flash analog-to-digital converter. Digitized pulse heights are processed and formatted for output by a microprocessor system.

The preliminary software flowcharts are shown in Figures 10, 11 and 12. The power up sequence and the program executive (the main microprocessor loop) are shown in Figure 10. Following the power up sequence, telemetry output and various housekeeping tasks are handled in the main loop, which runs in the background. Each of the six ASP's, as well as the serial command/data interface, are handled via interrupts.

The ASP interrupt processing flow chart is shown in Figure 11. If a detector is struck by an incident particle which deposits more than 50 keV in the detector, an interrupt is generated. The resulting dose is read by the microprocessor and various counters are incremented appropriately. Eight (8) data entities, as shown in Table 3, are generated for each detector.

The serial input interrupt processing flow chart is shown in Figure 12. An interrupt is generated whenever a command is received from the spacecraft. Of the several commands which have been defined, as shown in Table 4, only the first two, the telemetry packet request commands, are currently addressed in Figure 12. Under normal conditions, telemetry packet request commands are to be received from the spacecraft at a fixed rate of once per second. Housekeeping telemetry packets, as defined in Table 5, will be used extensively to verify proper instrument operation at initial turn on. They will also be used, to a lesser extent, to verify proper operation at all subsequent turn ons. Once proper Dosimeter operation is established, normal data packets, as defined in Tables 6 and 7, are used to transfer all primary science data (PSD), and some housekeeping data, to the spacecraft. Note that the PSD is time multiplexed. The PSD for one detector is transferred to the spacecraft in each normal data packet. Thus six (6) data packets (6 seconds) are required to read all of the PSD, and each detector's PSD is accumulated for six (6) seconds. The normal telemetry packet data accumulation and transfer timing is shown in Figure 13.

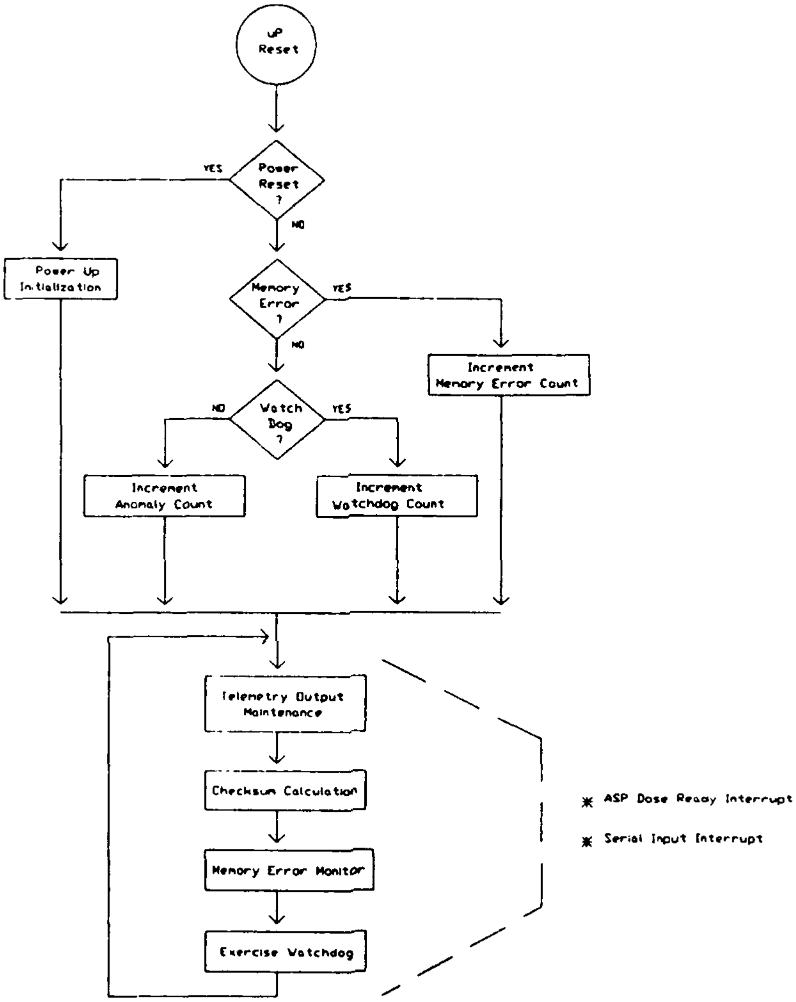

Figure 10. POWER UP AND PROGRAM EXECUTIVE SOFTWARE FLOW CHART

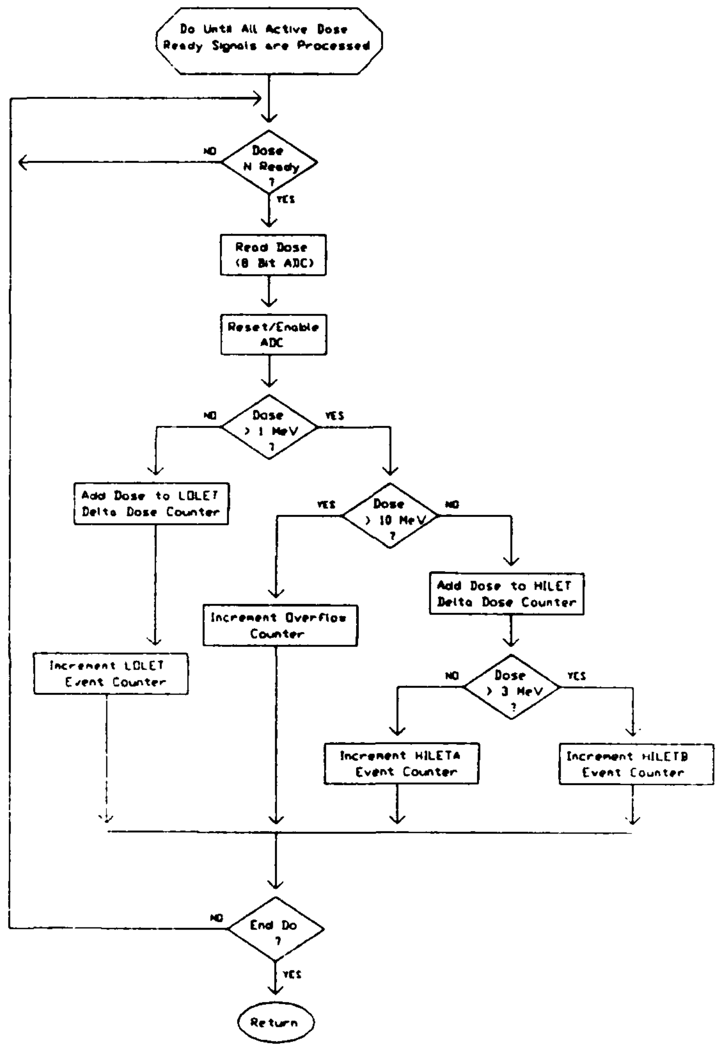

Figure 11. ASP INTERRUPT PROCESSING SOFTWARE FLOW CHART

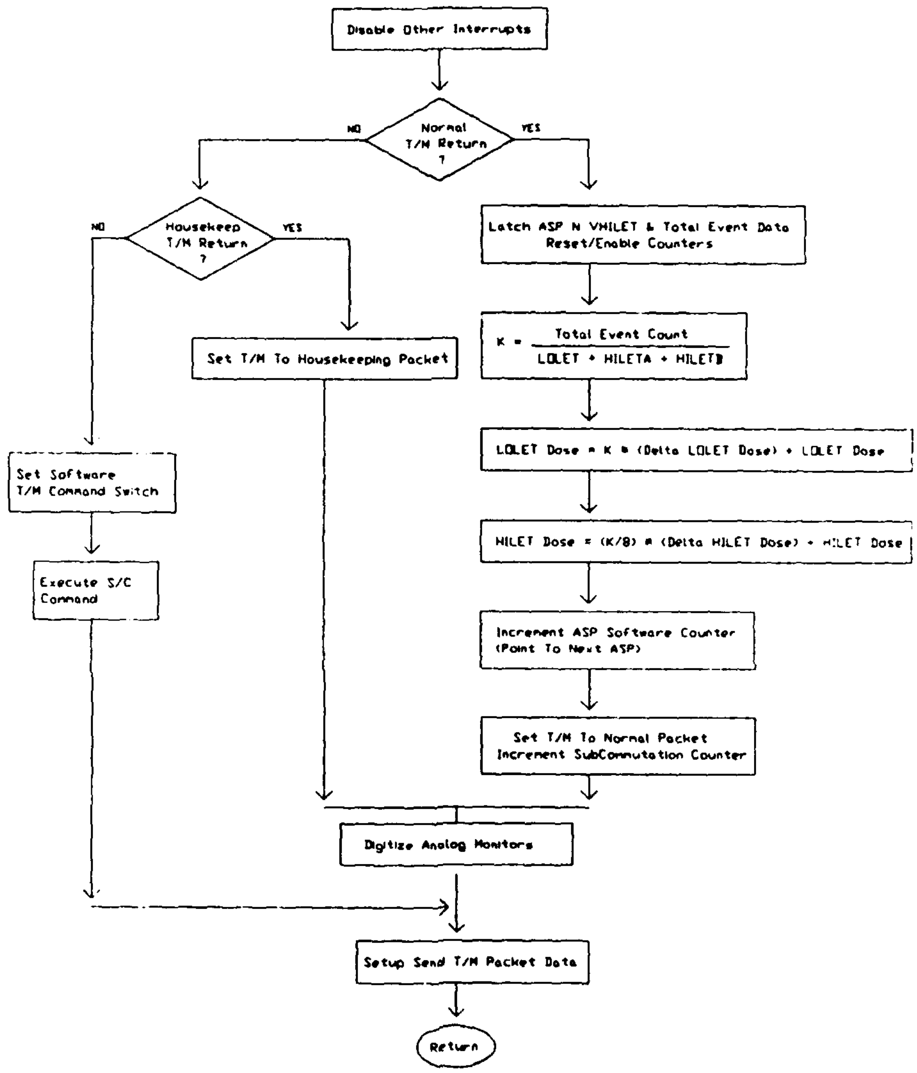

Figure 12. SERIAL COMMAND/DATA INTERRUPT SOFTWARE FLOW CHART

Table 3.
PRIMARY SCIENCE DATA ENTITIES

Entity	Mneumonic
Processed 50 keV to 1 MeV Event Count	LOLET COUNT
Processed 1 MeV to 3 Mev Event Count	HILETA COUNT
Processed 3 Mev to 10 MeV Event Count	HILETB COUNT
Processed Digital to Analog Converter Overflow Event Count (≥ 10 MeV)	OVERFLOW COUNT
Very High Energy Deposition Event Count (≥ 40 MeV for D1A, D1B, D2A, D2B and D3) (≥ 75 MeV for D4)	VHILET COUNT
Total Event Count (≥50 keV)	TOTAL COUNT
50 keV to 1 MeV Dose	LOLET DOSE
1 MeV to 10 MeV Dose	HILET DOSE

Table 4.
DOSIMETER COMMANDS

Second Byte MSB LSB 8 7 6 5 4 3 2 1	First Byte MSB LSB 8 7 6 5 4 3 2 1	Action/Response/Comments
0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0	Return normal telemetry packet Note - This command must be sent at 1 second ± 0.01 second intervals for normal Dosimeter operation
0 0 1 0 0 0 0 0	0 0 0 0 0 0 0 0	Return housekeeping telemetry packet
0 1 0 0 0 0 0 0	0 0 0 0 0 0 0 0	Reset dose counters
0 1 0 0 0 0 0 1	0 0 0 0 0 0 0 0	Spare
0 1 0 0 0 0 1 0	0 0 0 0 0 0 0 0	Spare
0 1 0 0 0 0 1 1	0 0 0 0 0 0 0 0	Enable data memory EDAC
0 1 0 0 0 1 0 0	0 0 0 0 0 0 0 0	Disable data memory EDAC
0 1 0 0 0 1 0 1	0 0 0 0 0 0 0 0	Reset fault flags
0 1 0 0 0 1 1 0	0 0 0 0 0 0 0 0	Test watchdog
0 1 1 A A A A A	A A A A A A A A	Power down PROM and run out of RAM (AA...A = 13 bit starting address)
1 0 0 A A A A A	A A A A A A A A	Power up PROM and run out of PROM (AA...A = 13 bit starting address)
1 0 1 C C C C C 1 1 0 A A A A A 1 1 1 0 0 0 0 0 . . . . 1 1 1 0 0 0 0 0	C C C C C C C C A A A A A A A A D D D D D D D D . . . . D D D D D D D D	Upload block of data to Dosimeter RAM (CC...C = 13 bit data byte count) (AA...A = 13 bit starting address) (DD...D = 8 bit data byte)

LSB is the first bit shifted out

Table 5.
HOUSEKEEPING TELEMETRY PACKET DATA ASSIGNMENT

Byte No.	Bits	Contents
1	0-7	Frame ID (Most Significant Bit = 1 identifies housekeeping packet)
2	0-7	D1A Detector Bias Voltage Monitor
3	0-7	D1B Detector Bias Voltage Monitor
4	0-7	D2A Detector Bias Voltage Monitor
5	0-7	D2B Detector Bias Voltage Monitor
6	0-7	D3 Detector Bias Voltage Monitor
7	0-7	D4 Detector Bias Voltage Monitor
8	0-7	D1A Reference Voltage Monitor
9	0-7	D1B Reference Voltage Monitor
10	0-7	D2A Reference Voltage Monitor
11	0-7	D2B Reference Voltage Monitor
12	0-7	D3 Reference Voltage Monitor
13	0-7	D4 Reference Voltage Monitor
14	0-7	+12V Monitor
15	0-7	+8V Monitor
16	0-7	+6V Monitor
17	0-7	+5V Monitor
18	0-7	+5V Reference Monitor
19	0-7	-6V Monitor
20	0-7	Regulated +8V Monitor
21	0-7	Detector Temperature Monitor
22	0-7	Electronics Temperature Monitor
23	0-3	Watchdog Count
23	4-7	Program Memory Fault Count
24	0-3	Data Memory Single Bit Fault Count
24	4-7	Data Memory Multiple Bit Fault Count

Table 5 (continued).
HOUSEKEEPING TELEMETRY PACKET DATA ASSIGNMENT

Byte No.	Bits	Contents
25	0	Data EDAC Memory Enable Flag (Active Lo)
25	1	Data EDAC Enable Flag
25	2	Program Memory ID, 0=PROM, 1=RAM
25	3	Spare
25	4	PROM Power On Flag
25	5	Spare
25	6	Spare
25	7	Spare
26	0-7	Last Command Most Significant Byte (Data Byte)
27	0-7	Last Command Least Significant Byte (Command Byte)
28	0	Program Memory Fault Flag
28	1	Spare
28	2	Data Memory Single Bit Fault Flag
28	3	Data Memory Multiple Bit Fault Flag
28	4	Spare
28	5	Data Memory EDAC Fault Flag
28	6	Watchdog Test Fault Flag
28	7	Watchdog Bite Flag
29	0-7	First Program Memory Error Least Significant Address Bits
30	0-4	First Program Memory Error Most Significant Address Bits
30	5-7	Number of Program Memory Errors Detected
31	0-7	First Data Memory Error Least Significant Address Bits
32	0-4	First Data Memory Error Most Significant Address Bits
32	5-7	Number of Data Memory Errors Detected
33	0-7	Telemetry Packet Checksum, Most Significant Byte
34	0-7	Telemetry Packet Checksum, Least Significant Byte

Table 6. NORMAL TELEMETRY PACKET DATA ASSIGNMENT		
Byte No.	Contents	Description
1	FRAME ID	Primary Science Data (PSD) Channel Identifier (= 0, 6, 12, 18 for D1A PSD data readout) (= 1, 7, 13, 19 for D1B PSD data readout) (= 2, 8, 14, 20 for D2A PSD data readout) (= 3, 9, 15, 21 for D2B PSD data readout) (= 4, 10, 16, 22 for D3 PSD data readout) (= 5, 11, 17, 23 for D4 PSD data readout) Also, Housekeeping Subcommutator Frame Identifier (see Table 7)
2	VHILET COUNT	PSD Very High Energy Deposition Event Count
3-5	TOTAL COUNT	PSD Total Event Count (≥ 50 keV)
6-8	LOLET COUNT	PSD Processed 50 keV to 1 MeV Event Count
9-11	HILETA COUNT	PSD Processed 1 MeV to 3 Mev Event Count
12-14	HILETB COUNT	PSD Processed 3 MeV to 10 MeV Event Count
15-19	LOLET DOSE	PSD 50 keV to 1 MeV Dose
20-24	HILET DOSE	PSD 1 MeV to 10 MeV Dose
25-26	OVERFLOW COUNT	PSD A to D Converter Overflow Count (≥ 10 MeV)
27	COMMAND MSB	Last Command MSB (Data Byte)
28	COMMAND LSB	Last Command LSB (Command Byte)
29	FAULT FLAGS	Bit 0 = Program Memory Fault Flag Bit 1 = Spare Bit 2 = Data Memory Single Bit Fault Flag Bit 3 = Data Memory Multiple Bit Fault Flag Bit 4 = Spare Bit 5 = Data Memory EDAC Fault Flag Bit 6 = Watchdog Test Fault Flag Bit 7 = Watchdog Bite Flag
30	PRG CKSUM MSB	Program Checksum, Most Significant Byte
31	PRG CKSUM LSB	Program Checksum, Least Significant Byte
32	HOUSEKEEPING	Subcommutated Housekeeping Data (see Table 7)
33	TM CKSUM MSB	Telemetry Packet Checksum, Most Significant Byte
34	TM CKSUM LSB	Telemetry Packet Checksum, Least Significant Byte

Table 7.
NORMAL TELEMETRY PACKET SUBCOMMUTATED DATA ASSIGNMENT

Frame ID (Byte 1 of Normal Telemetry Packet)	Bits	Housekeeping Data (Byte 32 of Normal Telemetry Packet)
0	0-7	D1A Detector Bias Voltage Monitor
1	0-7	D1B Detector Bias Voltage Monitor
2	0-7	D2A Detector Bias Voltage Monitor
3	0-7	D2B Detector Bias Voltage Monitor
4	0-7	D3 Detector Bias Voltage Monitor
5	0-7	D4 Detector Bias Voltage Monitor
6	0-7	D1A Reference Voltage Monitor
7	0-7	D1B Reference Voltage Monitor
8	0-7	D2A Reference Voltage Monitor
9	0-7	D2B Reference Voltage Monitor
10	0-7	D3 Reference Voltage Monitor
11	0-7	D4 Reference Voltage Monitor
12	0-7	+12V Monitor
13	0-7	+8V Monitor
14	0-7	+6V Monitor
15	0-7	+5V Monitor
16	0-7	+5V Reference Monitor
17	0-7	-6V Monitor
18	0-7	Regulated +8V Monitor
19	0-7	Detector Temperature Monitor
20	0-7	Electronics Temperature Monitor
21	0-3	Watchdog Count
21	4-7	Program Memory Fault Count
22	0-3	Data Memory Single Bit Fault Count
22	4-7	Data Memory Multiple Bit Fault Count
23	0	Data EDAC Memory Enable Flag (Active Lo)
23	1	Data EDAC Enable Flag
23	2	Program Memory ID, 0=PROM, 1=RAM
23	3	Spare
23	4	PROM Power On Flag
23	5	Spare
23	6	Spare
23	7	Spare

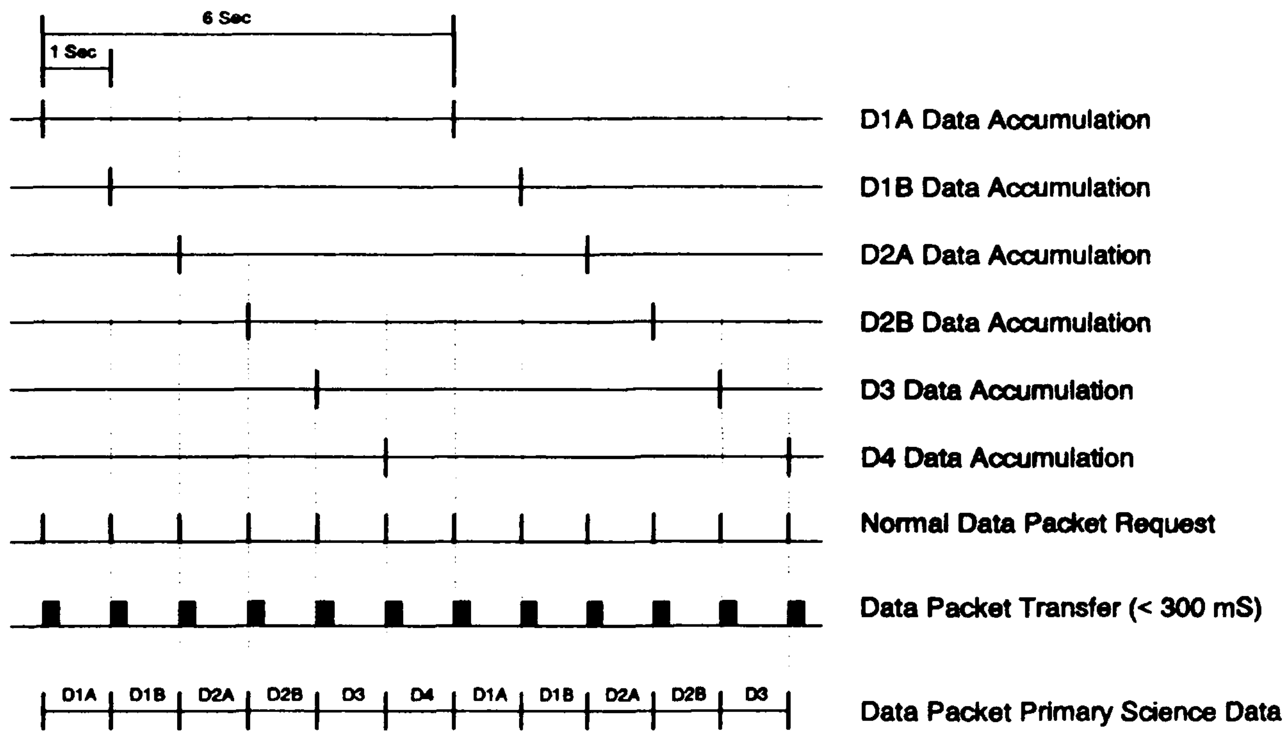

Figure 13. NORMAL TELEMETRY PACKET DATA ACCUMULATION AND TRANSFER TIMING

2.3 Detailed Electrical Design

2.3.1 Charge Sensitive Pre-Amplifier and Analog Signal Processor

The charge sensitive pre-amplifier (CSPA) design is essentially identical to an existing Panametrics design and is, therefore, complete. The design of the analog signal processor (ASP) has been completed, and schematic drawings have been generated. A breadboard of the CSPA and ASP circuitry has been fabricated and tested. Extensive tests at room ambient temperature, and over the temperature range of -55°C to +100°C, have been completed. The CSPA/ASP operates properly over this extended temperature range, and its stability over the anticipated Dosimeter operating temperature range (-25°C to +35°C) is well within that required for accurate dose measurements. Analog Signal Processor printed circuit board layout is currently in process, and it will be completed soon. Since 12 (total for 2 Dosimeters) of these boards are required, a single "engineering model" printed circuit board will be fabricated and tested prior to flight printed circuit board fabrication.

2.3.2 DC to DC Converter

The DC to DC Converter design has been completed, and schematic drawings have been generated. A breadboard has been fabricated and tested. Extensive tests at room ambient temperature, and over the temperature range of -55°C to +125°C, have been completed. The DC to DC Converter operates properly over this extended temperature range. DC to DC Converter printed circuit board layout will be started shortly.

2.3.3 Data Processor

A preliminary Data Processor design, based on an 80C86 microprocessor, was completed, and schematic drawings were generated. A breadboard was also fabricated. Harris Semiconductor, the 80C86 vendor, had assured us that radiation-hardened, single event upset immune, 80C86's would be available. However, just as the breadboard was completed, we were informed that the 80C86 microprocessor, although radiation-hardened, is quite susceptible to single event upsets. Therefore, the 80C86 based design was abandoned.

A new Data Processor design, based on the United Technology's 1750A microprocessor, was then undertaken. The 1750A is available radiation-hardened, and is single event upset immune. It is a 16 bit, Harvard Architecture, Reduced Instruction Set Computer (RISC), which can run at speeds of up to 12 MHz. It includes an on board Universal Asynchronous Receiver/Transmitter (UART) and two timers. The ASP data throughput rate will be significantly higher with the 1750A than it would have been with the 80C86.

Data Processor design, based on the United Technology's 1750A microprocessor, is in process. Rather than fabricating and testing a "conventional" breadboard of this circuitry, an initial printed circuit board layout will be completed, and a "breadboard" printed circuit board will be fabricated and tested. The printed circuit board layout will then be modified as required prior to fabrication of the flight printed circuit boards. The initial printed circuit board layout is currently underway.

2.4 Mass and Power

The preliminary upper limits for the instrument weight and power are 15 lbs and 10 watts at this time.

2.5 Parts Procurement

All long lead parts have been ordered, and most have been received. It is anticipated that all parts will be available as needed to support the instrument fabrication schedule.

3. SUMMARY

A second generation Dosimeter is being designed to fulfill the need for accurate radiation dose measurements. Two identical Dosimeters, a protoflight unit and a backup unit, are to be fabricated, tested and calibrated. The protoflight Dosimeter is to be integrated into the payload of the Advanced Photovoltaic Electronic Experiment (APEX) satellite, as part of the Photovoltaic Array Space Power Plus Diagnostics (PASP Plus) experiment. A summary of the second generation Dosimeter's characteristics is given in Table 8.

Table 8.
SUMMARY OF DOSIMETER CHARACTERISTICS

Sensors	6 planar silicon solid state detectors (SSD's) under 4 aluminum shields
Field of View	2π steradians
Data Fields	For each channel (SSD) counts in 6 deposited energy ranges, and the dose for 2 deposited energy ranges. VHILET counts (> 40 or 75 MeV) Total counts (> 0.050 MeV) LOLET counts (0.050 - 1 MeV) HILETA counts (1 - 3 MeV) HILETB counts (3 - 10 MeV) Dose Overflow counts (> 10 MeV) LOLET dose (0.050 - 1 MeV) HILET dose (1 - 10 MeV)
Output Data Format	272 bits serial, read out as 34 bytes, once per second. A total of 6 readouts is required to obtain all 6 channels. A total of 24 readouts is required to sample all Housekeeping data.
Command Requirements	2-byte commands initiate telemetry packet transmission, reset dose counters, determine PROM/RAM configuration, and upload data to RAM.
Size	5.5" H x 8" W x 9" D plus maximum 3.5" extension in D for Domes, excluding connectors and mounting tabs.
Mass	15.0 lbs
Power	10.0 W
Temperature Range	0°C to +35°C Nominal Operating -10°C to +45°C Maximum Operating -30°C to +60°C Non-Operating

REFERENCES

1. B. Sellers, R. Kelliher, F.A. Hanser, and P.R. Morel, "Design, Fabrication, Calibration, Testing and Satellite Integration of a Space-Radiation Dosimeter," report AFGL-TR-81-0354, AD A113085, (December 1981). Final Report for Contract No. F19628-78-C-0247.

2. P.R. Morel, F.A. Hanser, B. Sellers, J. L. Hunerwadel, R. Cohen, B. Kane and B. Dichter, "Fabricate, Calibrate and Test a Dosimeter for Integration into the CRRES Satellite," Report GL-TR-89-0152, ADA213812, (April 1989). Final Report for Contract No. F19628-82-C-0090.